USAARL Report No. 94-32

Apache Helicopter Seat Cushion Evaluation

By

Barclay P. Butler

and

Nabih M. Alem

Aircrew Protection Division

July 1994

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United States Army Aeromedical Research Laboratory
Fort Rucker, Alabama 36362-0577

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Roger W. Wiley

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Two prototypes of the AH-64 pilot seat cushions were evaluated against the standard cushion set by each of a group of 12 AH-64 instructor pilots after being exposed to simulated AH-64 vibration signatures for a period of 1 hour. Objective indications of vibration attenuation were obtained by measuring transfer functions across each cushion. Subjective pilot preferences also were obtained after each ride using a questionnaire. Results of the objective measurements indicate both the air-filled and the foam-filled prototypes reduced low-frequency transmission of vibration better than the standard cushions. Subjective responses indicate significant improvement in comfort and vibration absorption for the seat back and bottom cushions of both prototypes over the standard cushion set.

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Introduction

Seated operators in work environments often are required to spend long periods of time at their workstations while performing their primary duties. AH-64 Apache helicopter pilots are known to routinely spend up to 6 hours in their crewstation seat performing operations that include preflight, flight, and postflight tasks. Seat cushion design can impact directly on crew comfort and adversely affect mission performance. This study is an evaluation of two candidate replacement seat cushions, as compared to the standard seat cushion, for the AH-64 helicopter crew seat.

The Aviation Applied Technical Directorate* (AATD), Fort Eustis, Virginia, contracted with LME, Inc.* to design a replacement seat cushion set for the AH-64 Apache helicopter. Two cushion sets were designed with adjustable thigh and lumbar supports--one foam filled and one air filled. Prior to impact testing for crashworthy qualifications, AATD contacted the U.S. Army Aeromedical Research Laboratory (USAARL) to conduct a seat cushion comfort evaluation. This report documents the seat cushion comfort testing.

Methods

Twelve volunteer AH-64 Apache helicopter instructor pilots, recruited from D Company, 14th Aviation Battalion, Fort Rucker, Alabama, were exposed to AH-64 seat cushion sets using a repeated measures design. Seat cushion exposures were achieved by asking the subjects to sit atop the multiaxis ride simulator (MARS) in a partial AH-64 mockup crewstation. The mockup consisted of an AH-64 seat with collective, cyclic, and pedal controls arranged to be consistent with the placement of the AH-64 flight controls.

The repeated measures design was implemented as follows: three seat cushion sets (two candidate sets and the standard cushion set) were rotated through for each subject group. There were three groups consisting of four subjects each. Subjects were assigned randomly to the three groups. A total of 36 exposure tests were conducted.

Each of the 12 subjects was exposed to 1 hour of AH-64 simulated ride motion. This was repeated for each of the three seat cushion sets. A seat cushion set was comprised of a seat bottom, seat back, lumbar support, and an arm support. Subjects adjusted their seat position, pedal position, thigh, and lumbar support as they desired. Exposure to the remaining seat cushion

* See list of manufacturers.

sets was performed at the same time of the day on subsequent days.

Transfer functions are objective characterizations of the ability of a system to attenuate (or magnify) the transmission of vibrations through the system. The transfer functions for the seat cushions and seat backs were measured by using two B&K* model 2631 triaxial accelerometers for the seat panels proper, with one rigidly attached to the underside of the seat bottom and the other rigidly attached to the back side of the seat back. Two seat pad triaxial accelerometers, B&K model 4322, were used with one placed under the subject's buttock and on top of the seat bottom cushion, and the other placed behind the subject's back at the level of the upper thoracic spine and in front of the seat back cushion.

Three transfer functions were obtained for each accelerometer set with the Z-axis aligned out of the cushion, the X-axis aligned along the longitudinal axis parallel to the cushion surface, and the Y-axis aligned laterally and parallel to the cushion surface (Figure 1).

Accelerometer signals were amplified using Kistler* model 1430 charge amplifiers to obtain a sensitivity of 1 G/volt. Amplified accelerometer signals were recorded on a TEAC* XR-510 running at a tape speed of 4.8 cm/sec. Frequency response for this recording system was 0-1250 Hz.

Subjective assessments of seat cushion comfort were obtained from each subject following the 1-hour simulated ride exposure for each seat cushion set. Subjects filled out a questionnaire using a visual analog scale and rated each of 13 questions for the seat bottom and rated each of 17 questions for the seat back (Appendix F).

Simulated helicopter ride exposure was produced on the MARS facilities at USAARL. The MARS system is capable of reproducing field recorded triaxial acceleration signals in the 2-40 Hz range. Apache helicopter acceleration signals, previously recorded and available at USAARL for playback, were sampled by the MARS system and an iterative procedure reproduced the helicopter vibrations to within 0.5 dB. The chosen flight profile was a straight and level flight at normal cruise speed without wing stores. Simulated ride motion as reproduced at MARS and to which the subjects were exposed did not exceed the health and safety limits specified in AR 40-10 and ISO 2631.

Analysis

Transfer functions were generated from acceleration signals recorded during the testing phases using PC-based hardware and software. The analog signals were played back into antialias low-pass filters (Onsite TechFilter PC-16 card) to remove frequencies above 80 Hz. The filtered signals were passed to the analog-to-digital convertor (Metrabyte DAS-1601) which sampled each signal at the rate of 500 samples/second. The digital signals then were analyzed by the digital signal processing SnapMaster software. The main process to which digital signals were subjected was a transfer function block, tailored to apply an 8-second Hamming window in the time domain signal, then the transfer functions were averaged for 16 averages. Averaged transfer function data were exported to MicroSoft Excel for ensemble averaging across subjects for each seat cushion set.

Averaged transfer functions were processed further by integrating the response in the range of 4-8 and 20-40 Hz. The 4-8 Hz range was chosen because it is the maximally sensitive region for the Z-axis response. The Z-axis motion is the dominant response for helicopter vibration. The 20-40 Hz region was selected to represent the high frequency attenuation. A multiple comparison of means test was performed on the integrated response for seat cushion sets using Systat* statistical software run on a 286-based PC. Only Z-axis responses were analyzed using statistical methods.

Subjective responses from the questionnaires were analyzed by initially coding the responses from 1 through 7 for each question and applying a Tukey Honestly Significant Difference test. All statistical tests were performed at the $p \leq 0.1$ level.

A final questionnaire was used to assess the acceptance of the arm support, inflation bulbs and foam wedges, and lumbar support (Appendix G), and followed the last simulated ride exposure. Analysis of this data consisted of reporting means and standard deviations.

Results

Transfer function data are shown in Figures 2, 3 and 4, for the air filled (configuration A), foam filled (configuration B), and standard seat cushion sets (configuration C), respectively. Each figure has the averaged transfer function for the seat bottom X (a), Y (b), and Z (c), and the seat back X (d), Y (e), and Z (f).

The low frequency integrated response is shown in Figure 5, with significant differences found for the air and foam back cushions as compared to the standard back cushion. Figure 6 shows the high frequency integrated response with significant differences found for the air and foam bottom cushion as compared to the standard bottom cushion.

Subjective responses for the seat bottom showed significant differences for 3 of the 13 questions regarding thickness of the seat cushion (question 3), the vibration absorption (question 12), and the overall comfort (question 13). Figure 7 shows the coded scores where a lower score indicates a preference for the characteristic. Subjective responses for the seat back also showed significant differences for 3 of the 17 questions regarding thickness of the lumbar support (question 4), the covering material thickness (question 12), and the overall comfort (question 17). Figure 8 shows the coded scores where a lower score indicates a preference for the characteristic.

Subjective responses for the questionnaire addressing the arm support attachment site, the potential interference with the inflation bulbs and foam wedges with the controls, and the lumbar support is shown in Table 1. Responses were coded similarly using a range of 1-7 with a lower score indicating a characteristic that is "liked" or is "acceptable." A cell in Table 1 with no numbers indicates this question received no responses.

Discussion

Transfer function data showed that, for the Z axis and for the bottom cushion, the air and foam cushions had significantly greater attenuation over that of the standard cushion back for the higher frequency range of 20-40 Hz. This indicates the air and foam cushions reduced the amount of high frequency vibration transmitted to the subject's buttocks. That both cushions showed similar responses is not surprising because the foam wedges and air support primarily are over the thigh region. The subject's buttocks are supported by a similar covered foam material for both cushions. This reduction in transmitted vibration also is supported by the subjective responses with a significant difference found in favor of increased vibration absorption between the prototype cushions and the standard cushion. Subjective responses also showed significant differences in overall comfort with the prototype seat bottom cushions deemed more comfortable than the standard seat bottom cushion.

The seat back transfer function data showed that, for the Z axis and for the back cushion, the air and foam cushions had significantly greater attenuation over that of the standard cushion back for the lower frequency range of 4-8 Hz. This indicates the air and foam cushions reduced the amount of gain in the low frequency range and transmitted less vibration to the subject's back. Subjective comfort data also supported the prototype seat back cushions in favor of the standard seat back cushion.

Care must be taken when interpreting the seat back transfer function data showed in Figures 1, 2, and 3. Transfer function calculations for the seat cushions assume constant contact between the input response surface and the output response surface. A break in the contact of the subject's back with the seat pad accelerometer would render the transfer function calculations invalid. Care was taken to ensure that data records used in the seat back transfer functions had good contact between the subject's back and the seat pad accelerometer. Even with this effort, contact was often times light and subject to error.

A subjective response that was not assessed in the questionnaires, but was volunteered by a majority of the subjects, was that the prototype lumbar supports needed to be "butterfly" shaped similar to that found in the standard seat cushion lumbar support. The rectangular shape of the foam filled and air filled lumbar support had a tendency to push the subjects out of the seat pan, as opposed to supporting the lumbar region of the back.

The final questionnaire surveying the arm support, the lumbar support, and potential interference with the control, indicated strong responses from three questions. Subjects appeared to dislike the arm attachment to the thigh, dislike the foam adjustable lumbar support, and found no interference with the foam wedges with the cyclic.

Conclusion

Objective transfer function results indicate the prototype air-filled and foam-filled seat cushions perform better than the standard AH-64 seat cushion for the seat bottom cushion in attenuating higher frequency vibrations. Low frequency gain is reduced over that of the standard seat cushion set for the air- and foam-filled prototype seat back cushion. Subjective responses indicate significant differences in comfort assessments for seat back and seat bottom cushions, and improved vibration absorption for the seat bottom cushion.

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Donelson, Sarah M., and Gordon, Claire C. 1991. 1988 Anthropometric survey of U.S. Army personnel: pilot summary statistics. Natick, MA: United States Army Natick Research, Development and Engineering Center. TR-91-040.

International Organization for Standardization. 1985. Evaluation of human exposure to whole-body vibration, Part 1: General requirements. ISO-2631. 2nd edition. 1985-05-15.

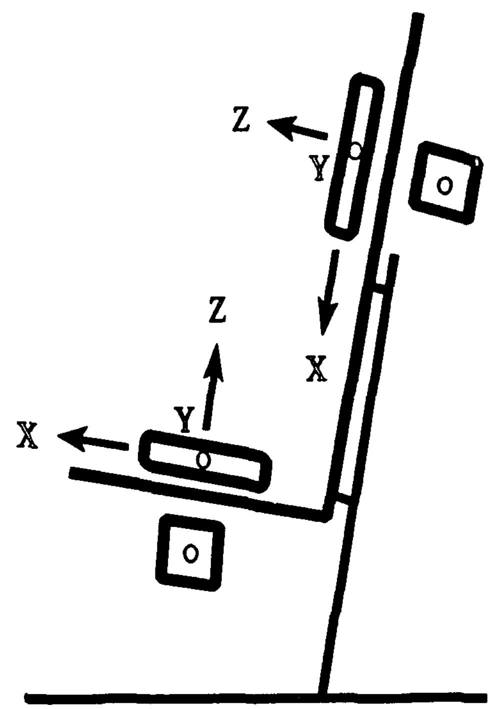


Figure 1. Placement of seat pad accelerometers (rectangles) and seat pan accelerometers (squares) with axis orientations. Seat pan accelerometers have the same orientation as the seat pad accelerometers.

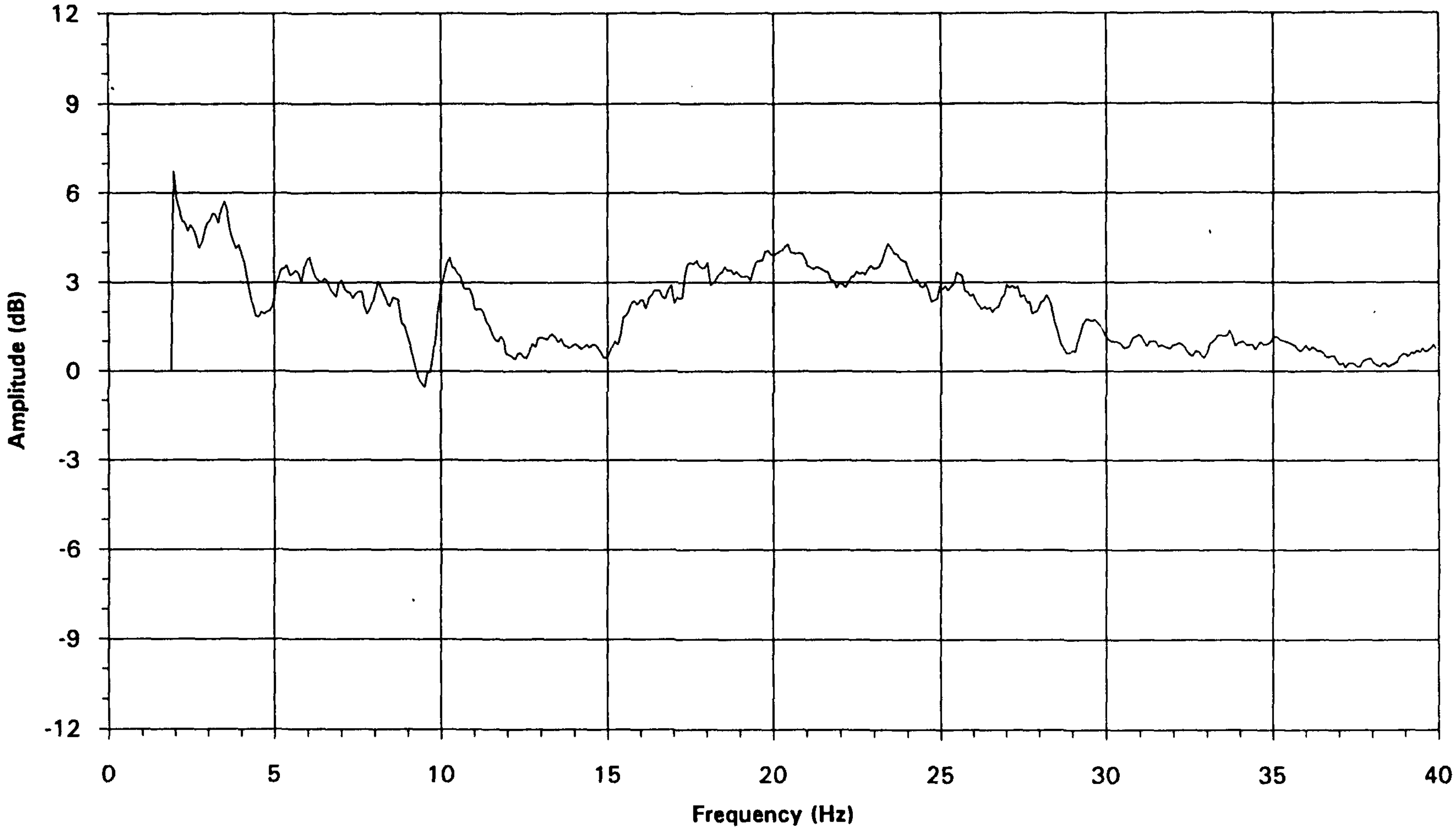


Figure 2-a. Transfer function for the air cushion set: bottom cushion, X-direction.

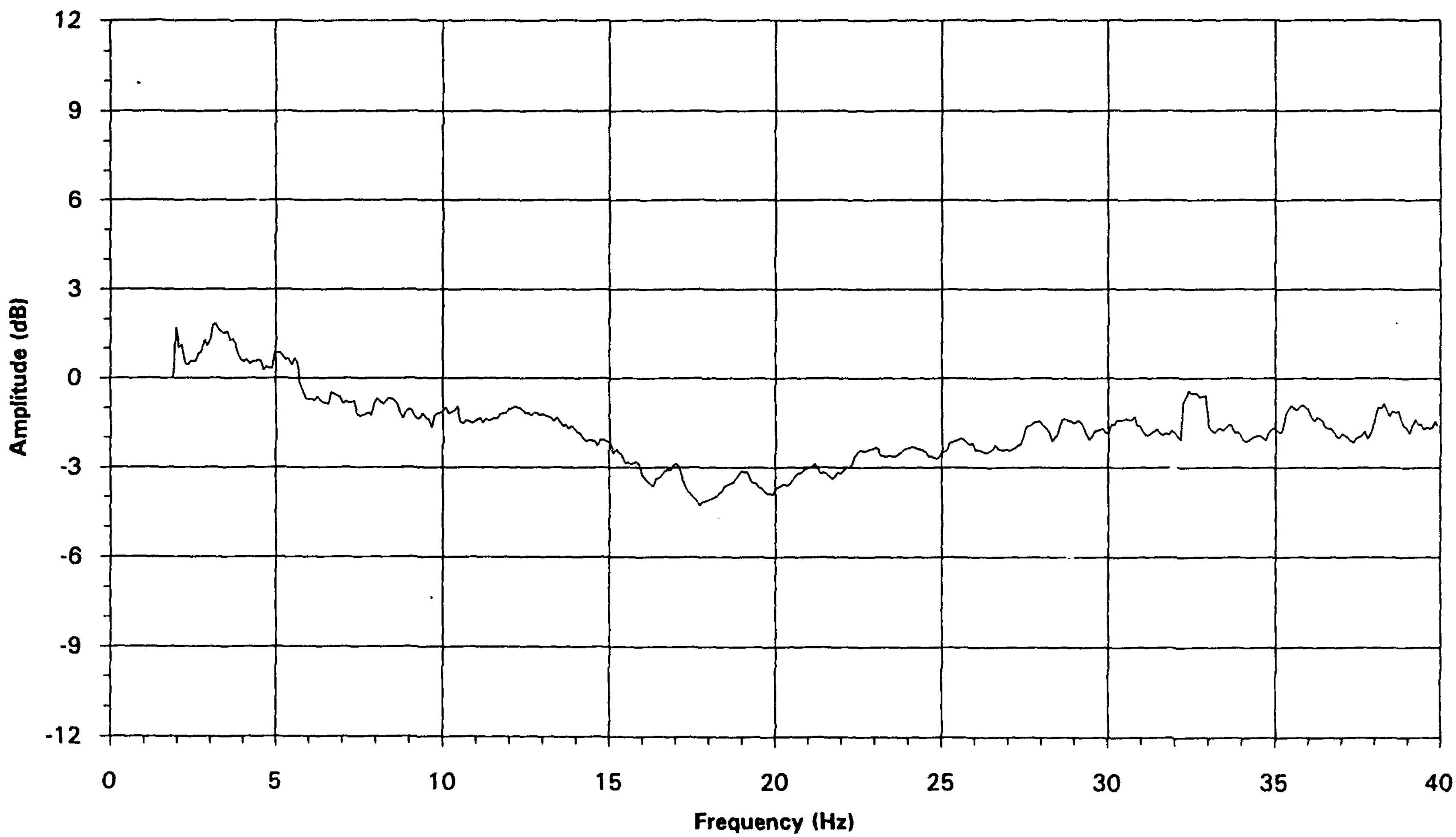


Figure 2-b. Transfer function for the air cushion set: bottom cushion, Y-direction.

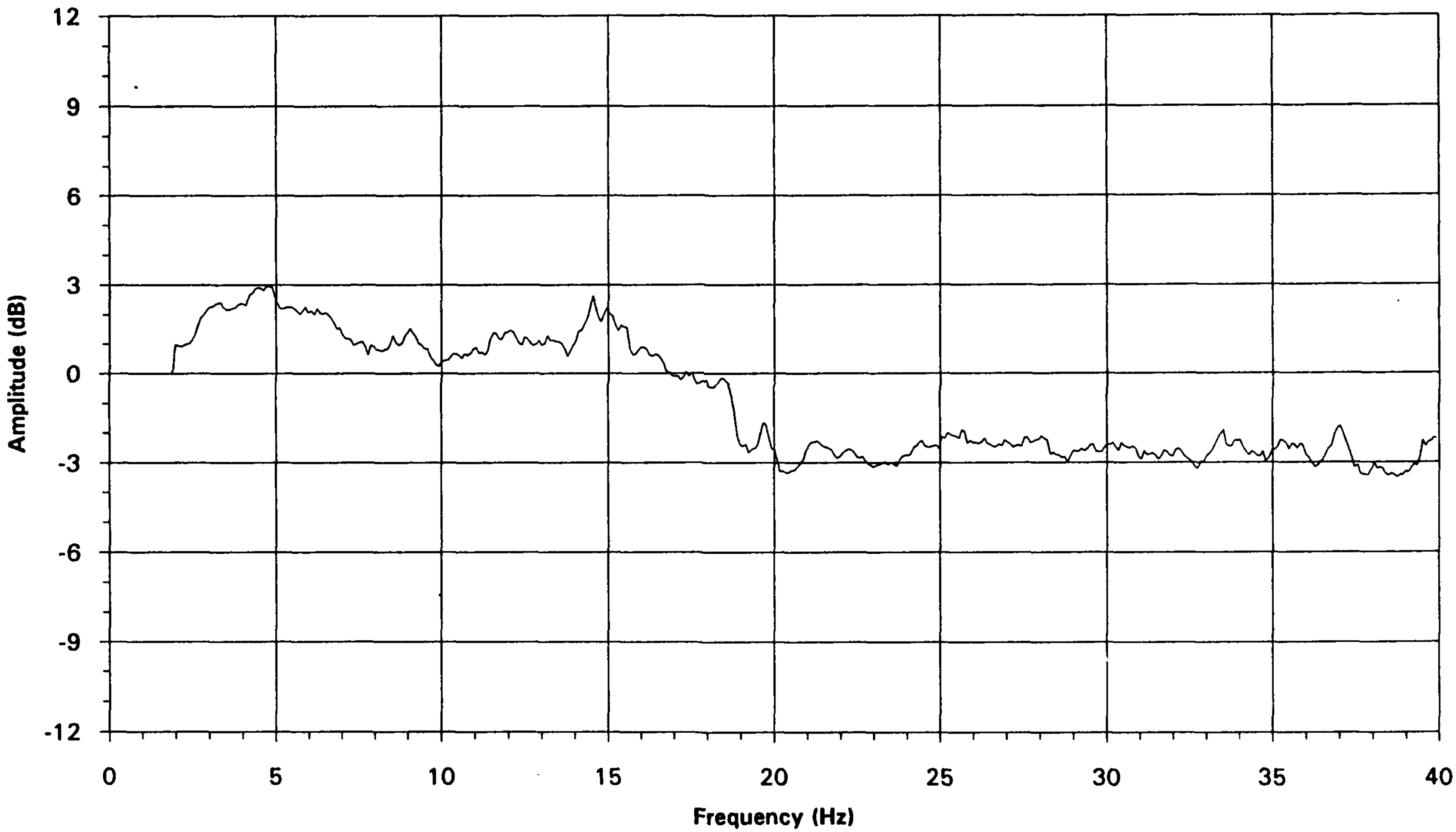


Figure 2-c. Transfer function for the air cushion set: bottom cushion, Z-direction.

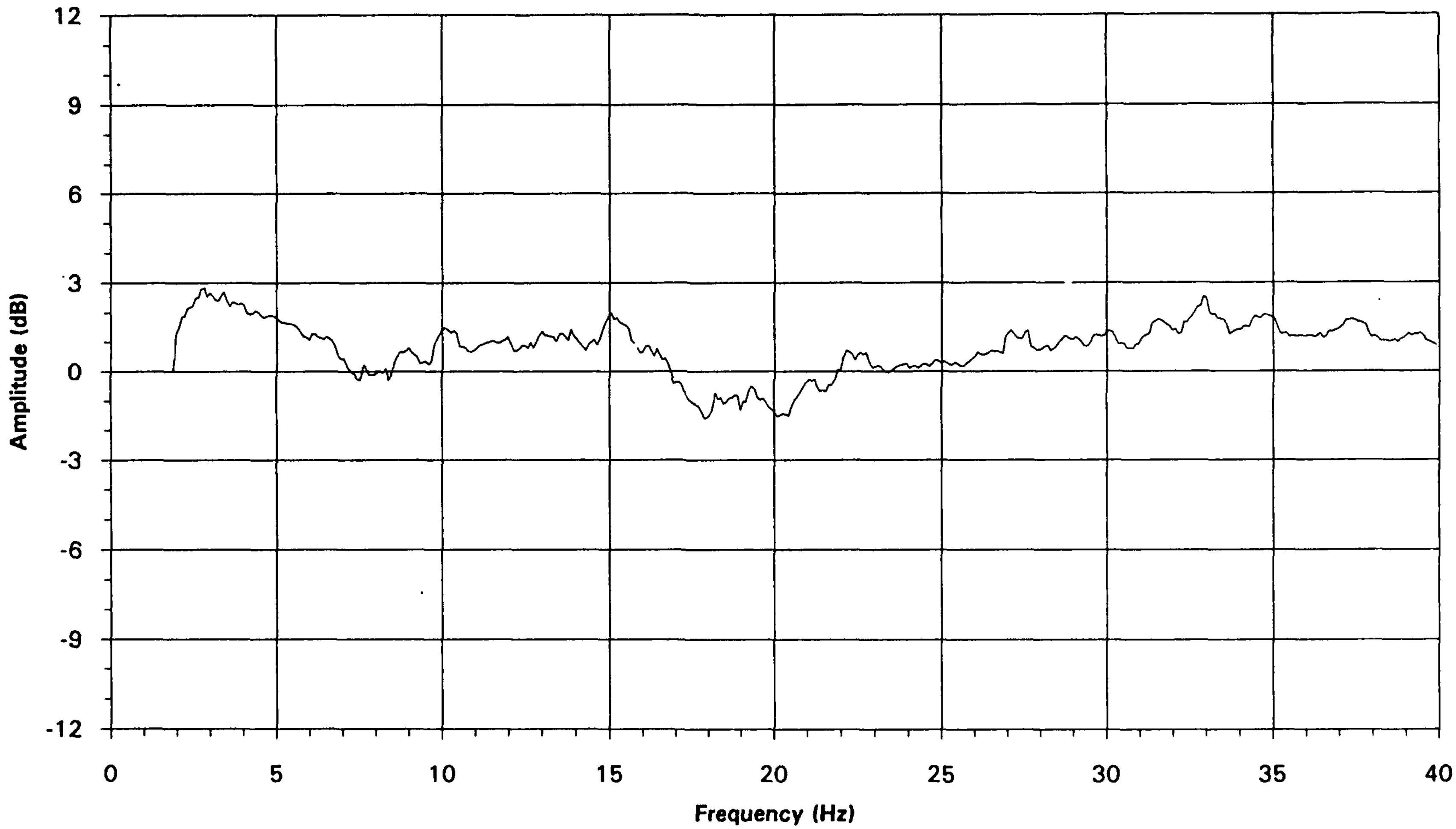


Figure 2-d. Transfer function for the air cushion set: back cushion, X-direction.

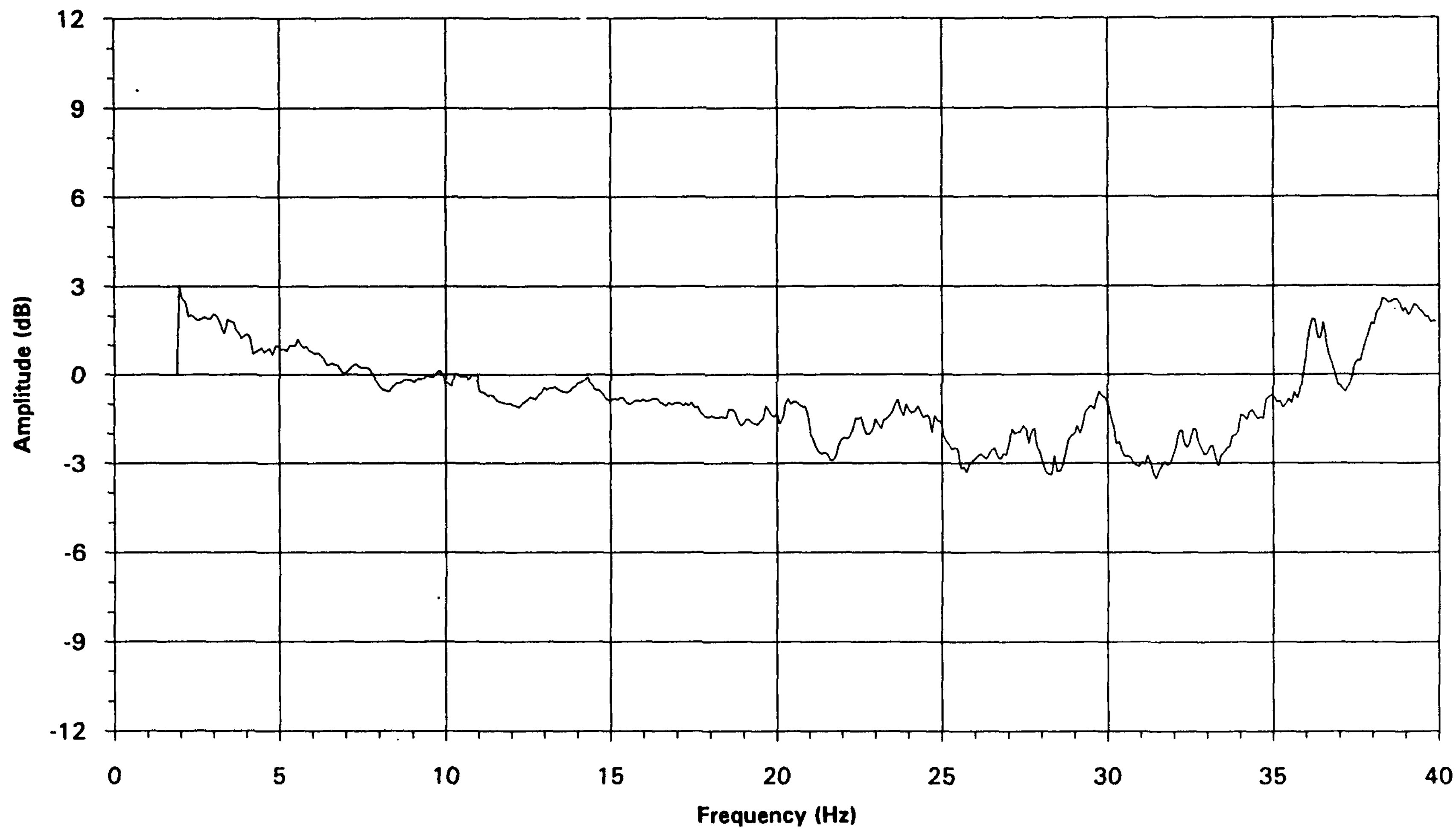


Figure 2-e. Transfer function for the air cushion set: back cushion, Y-direction.

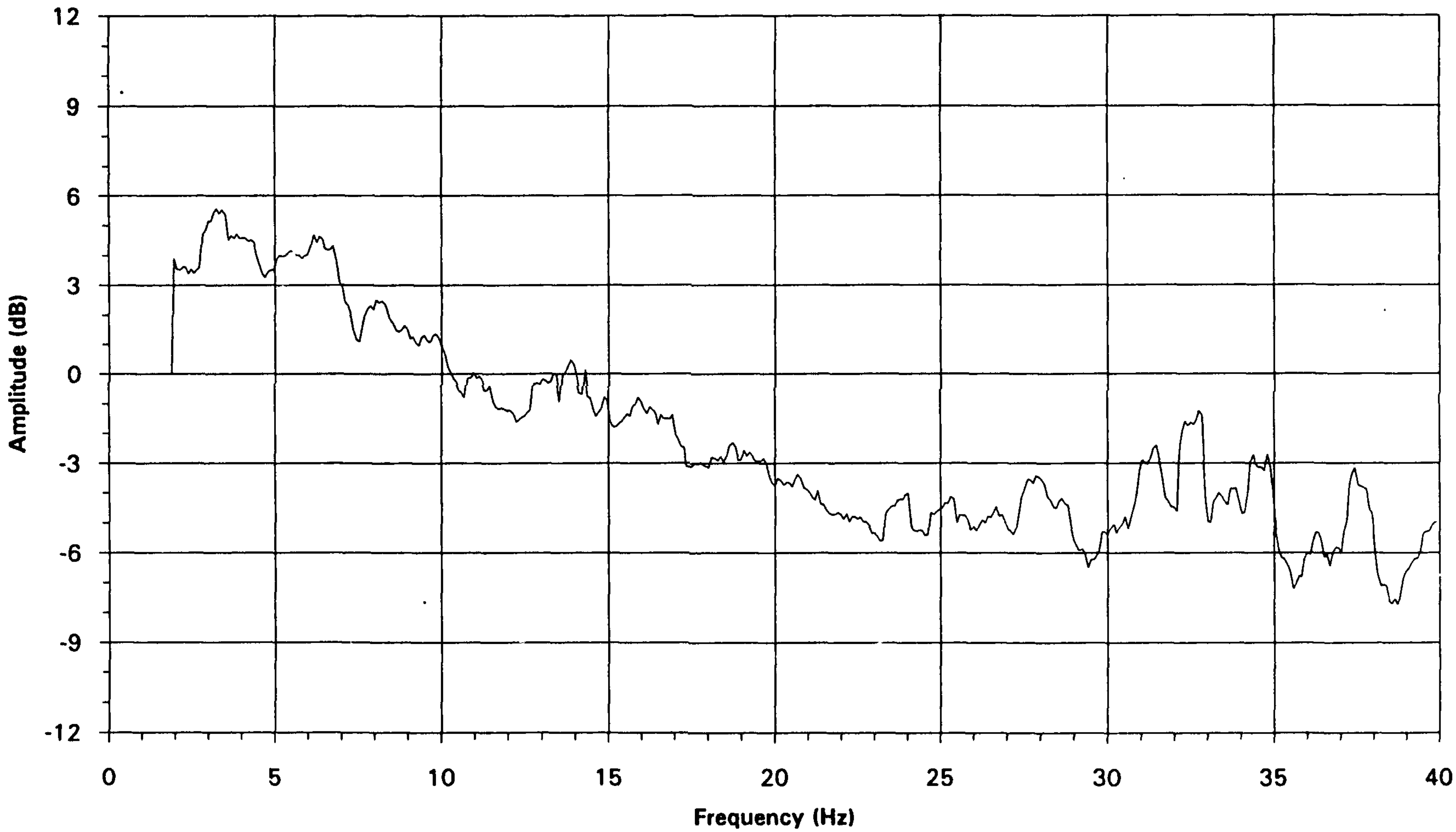


Figure 2-f. Transfer function for the air cushion set: back cushion, Z-direction.

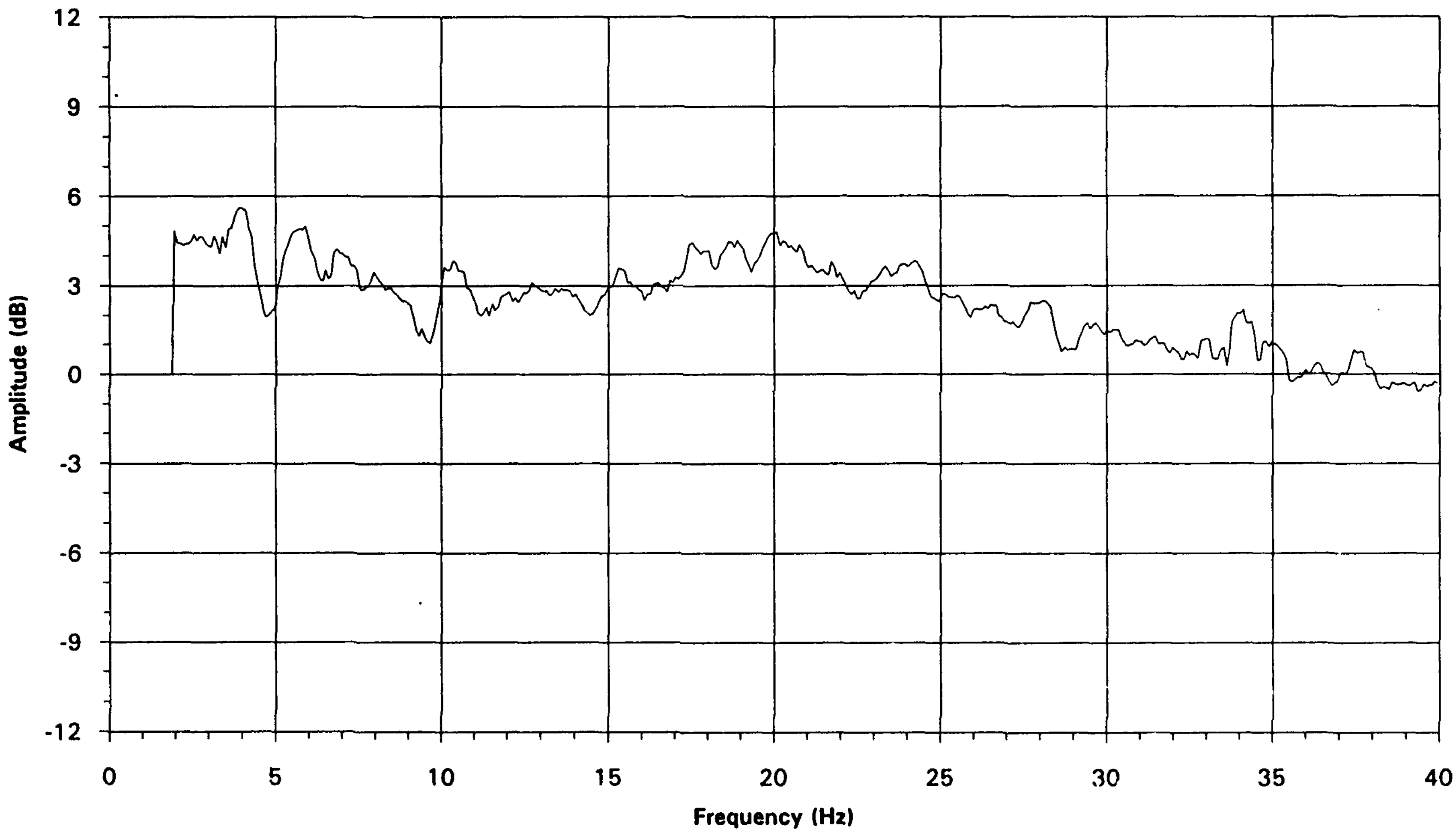


Figure 3-a. Transfer function for the foam cushion set: bottom cushion, X-direction.

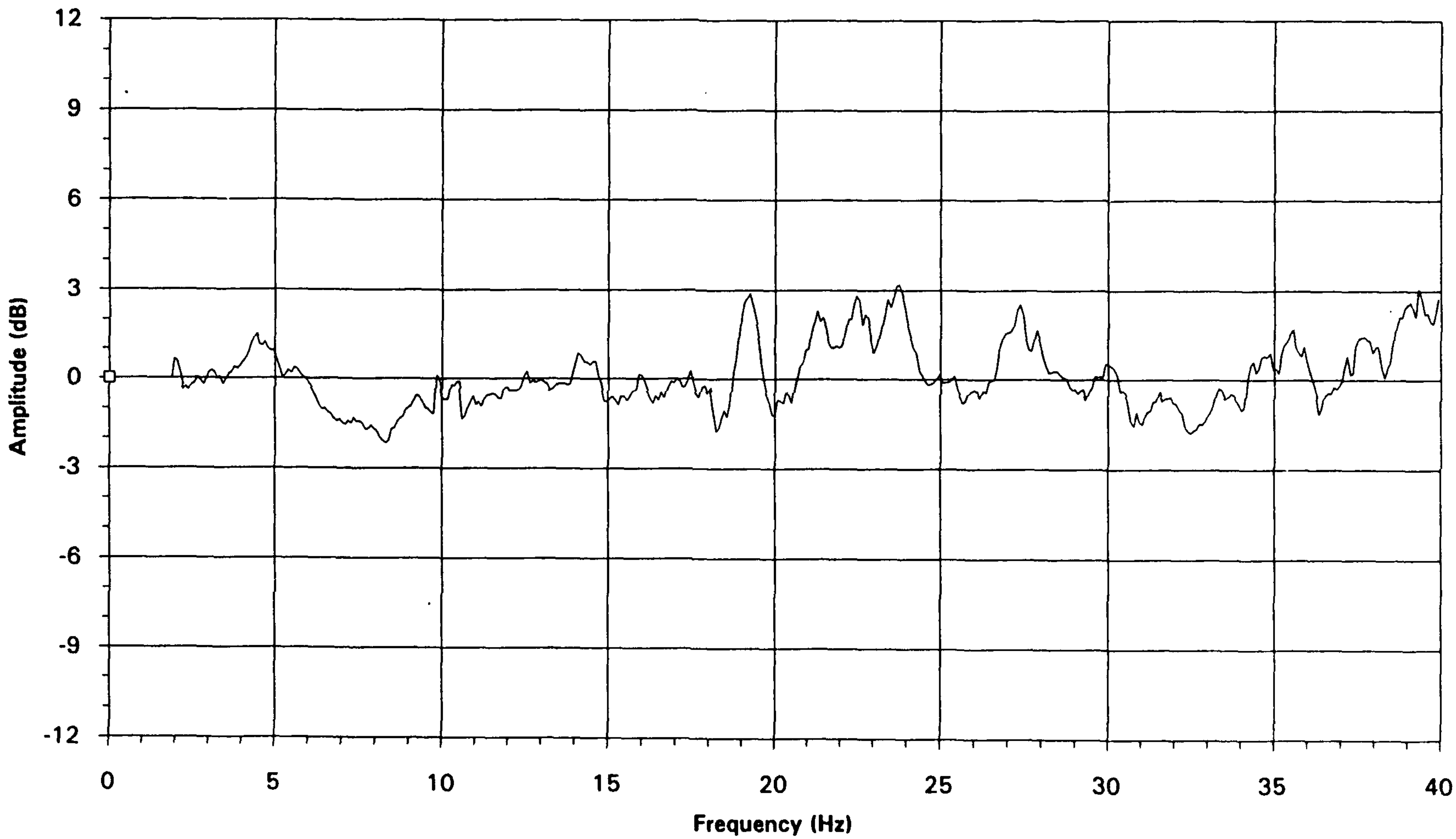


Figure 3-b. Transfer function for the foam cushion set: bottom cushion, Y-direction.

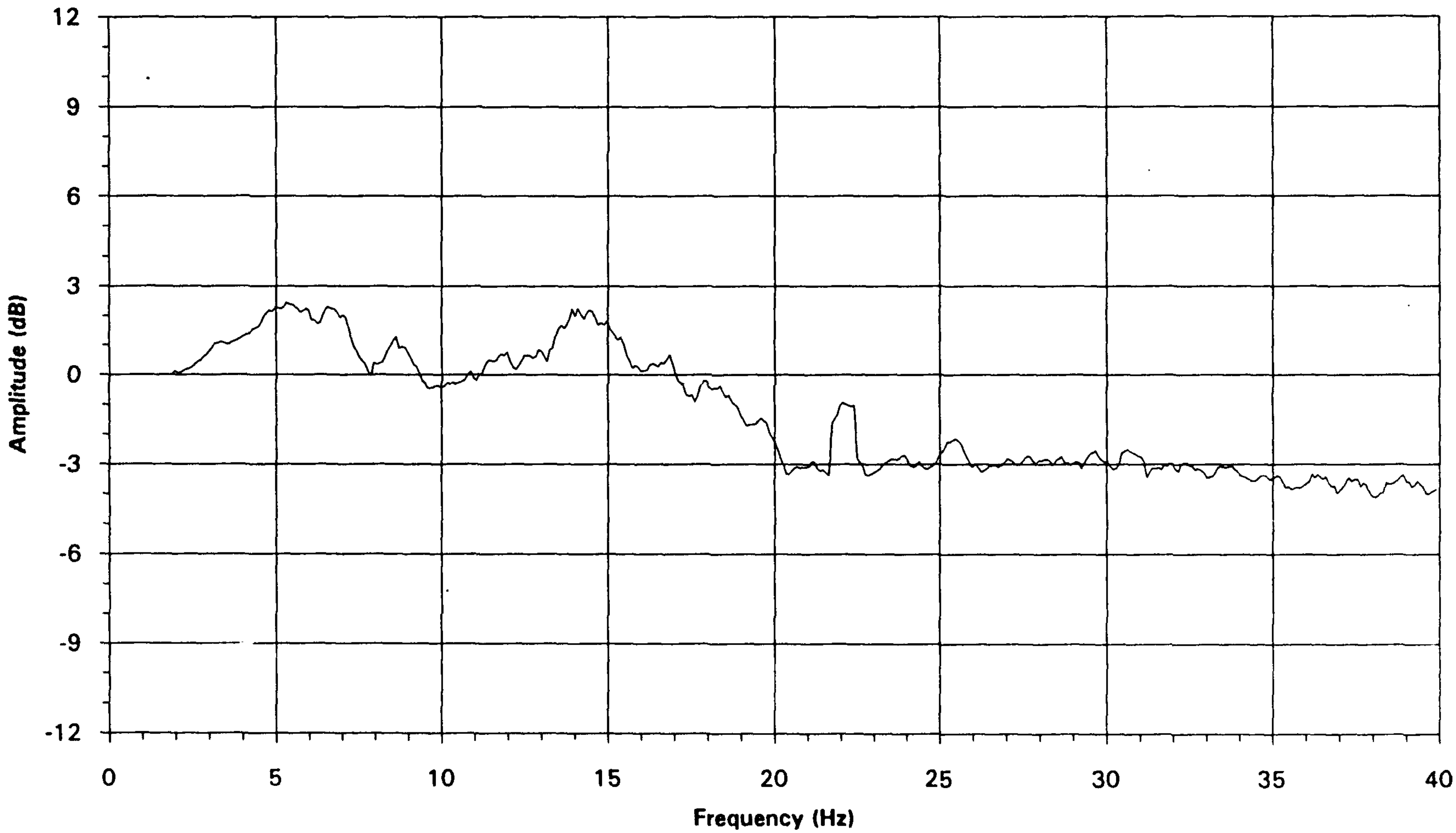


Figure 3-c. Transfer function for the foam cushion set: bottom cushion, Z-direction.

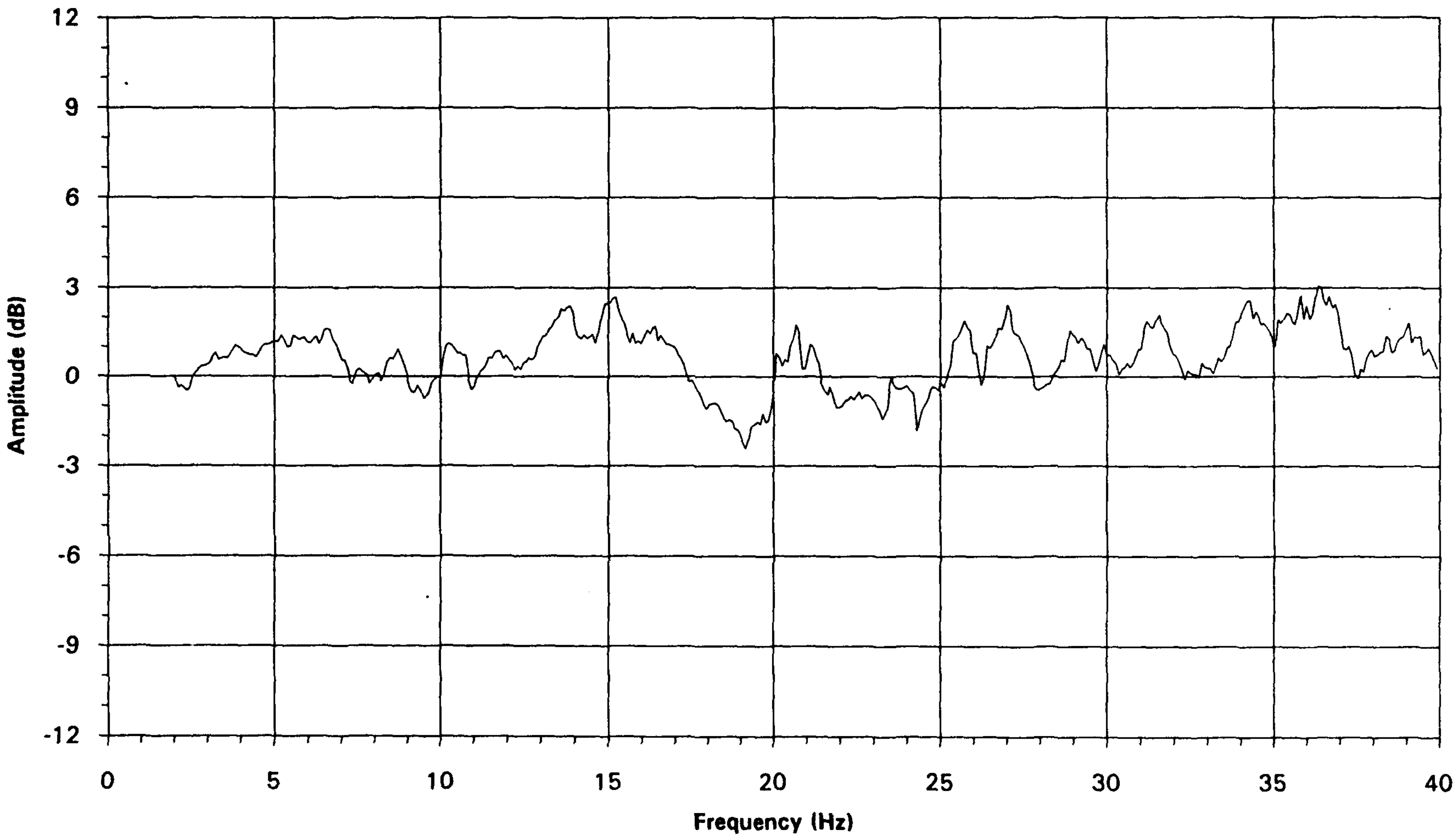


Figure 3-d. Transfer function for the foam cushion set: back cushion, X-direction.

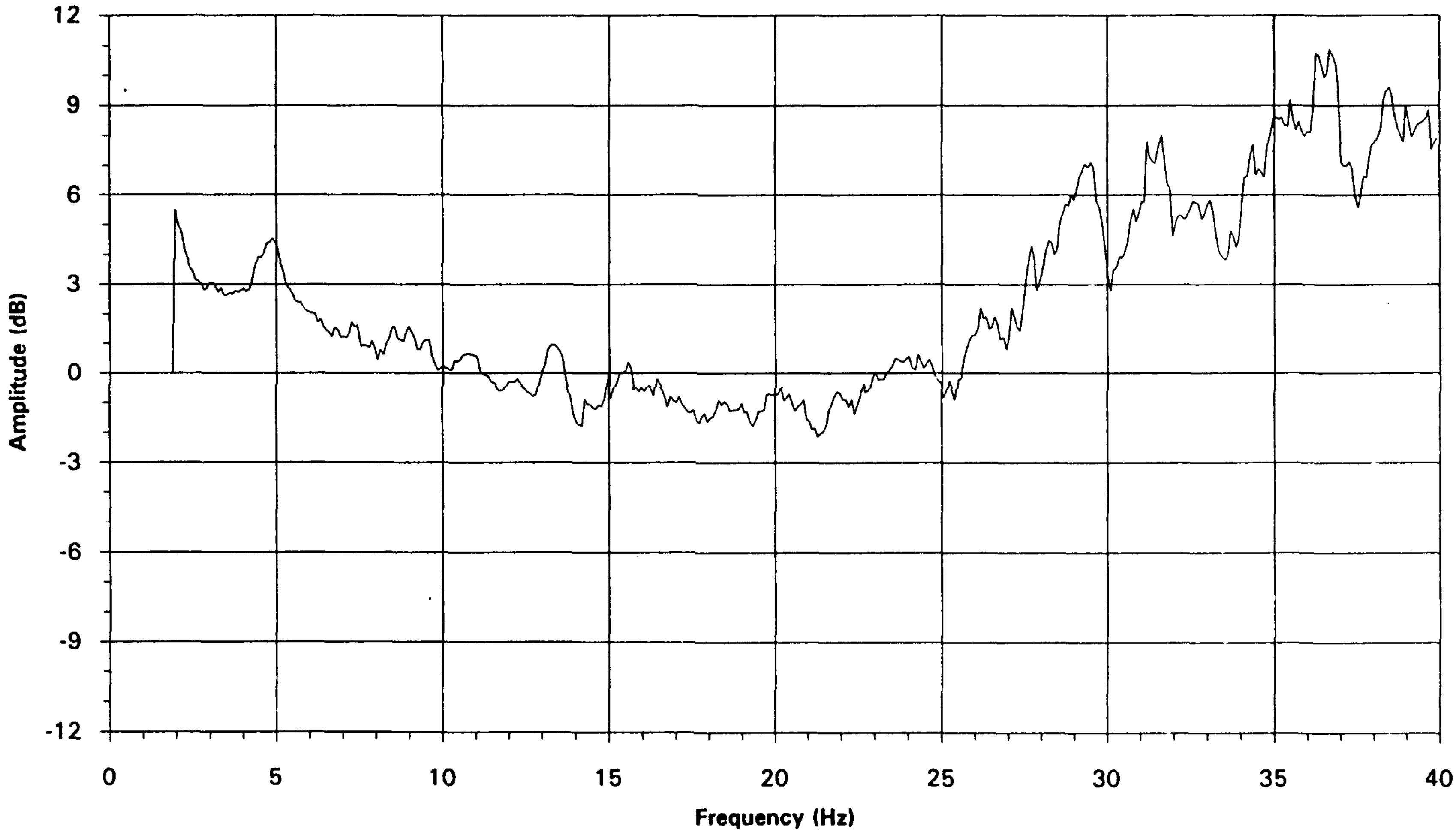


Figure 3-e. Transfer function for the foam cushion set: back cushion, Y-direction.

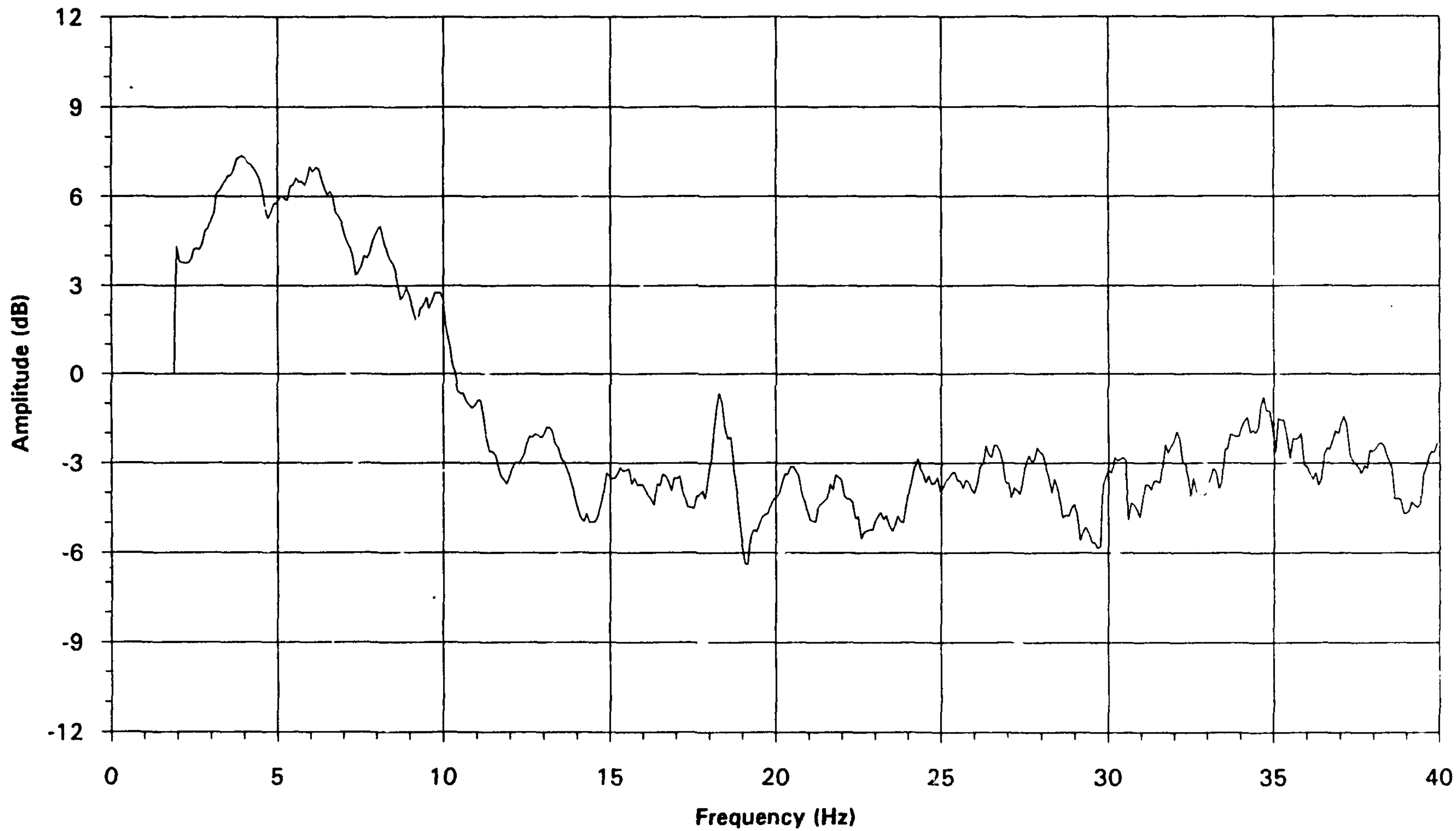


Figure 3-f. Transfer function for the foam cushion set: back cushion, Z-direction.

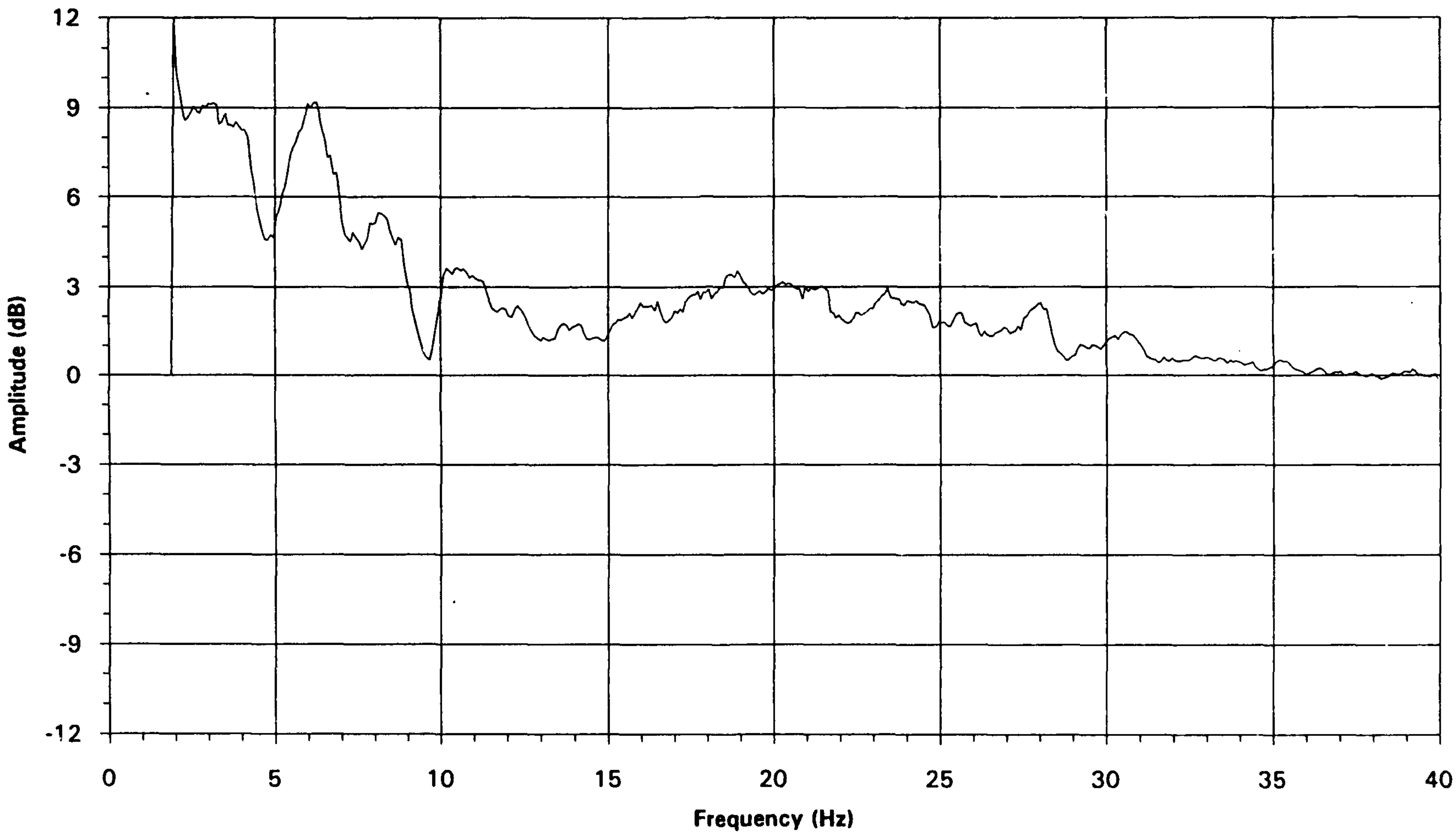


Figure 4-a. Transfer function for the standard set: bottom cushion, X-direction.

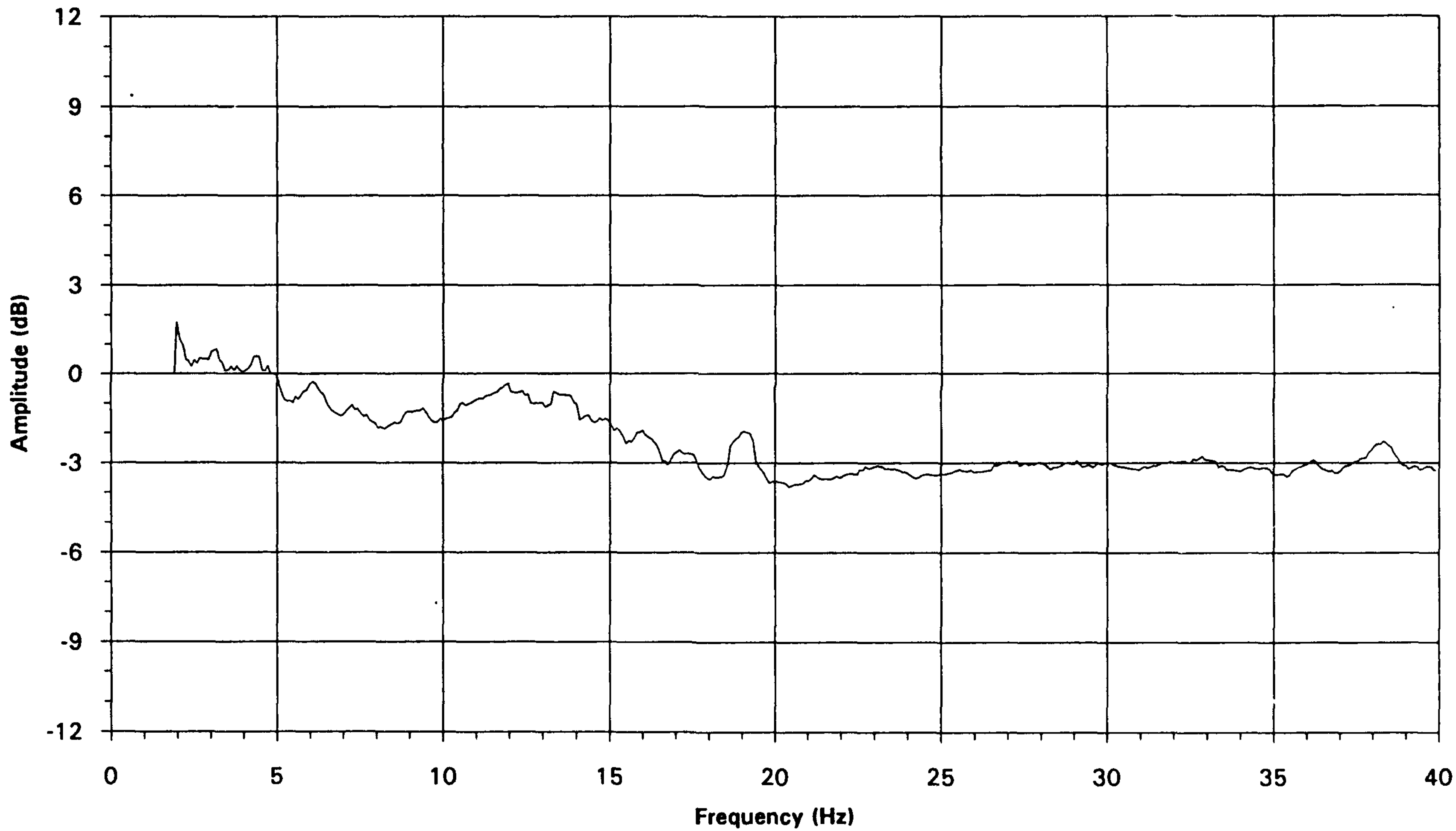


Figure 4-b. Transfer function for the standard set: bottom cushion, Y-direction.

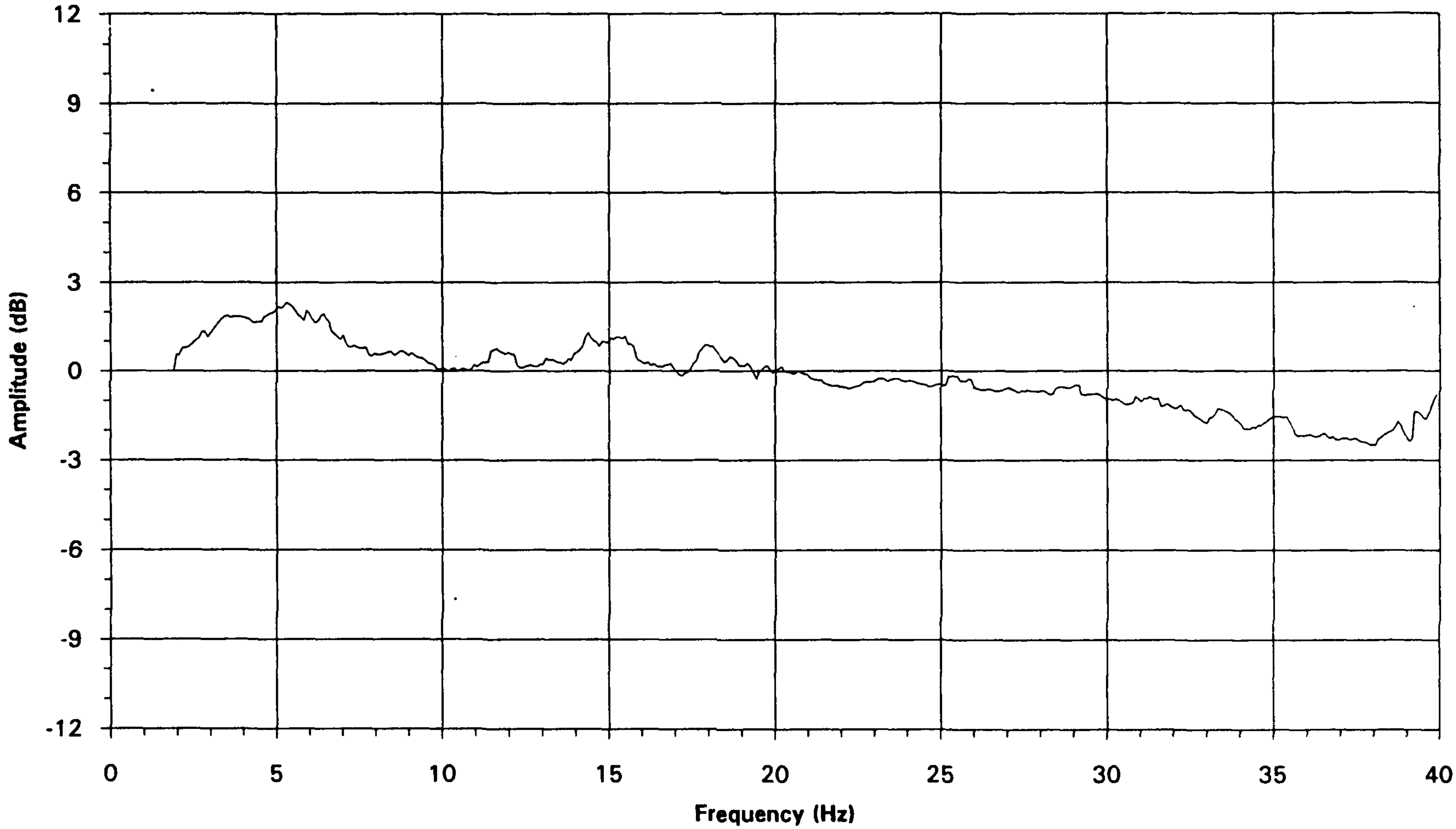


Figure 4-c. Transfer function for the standard set: bottom cushion, Z-direction.

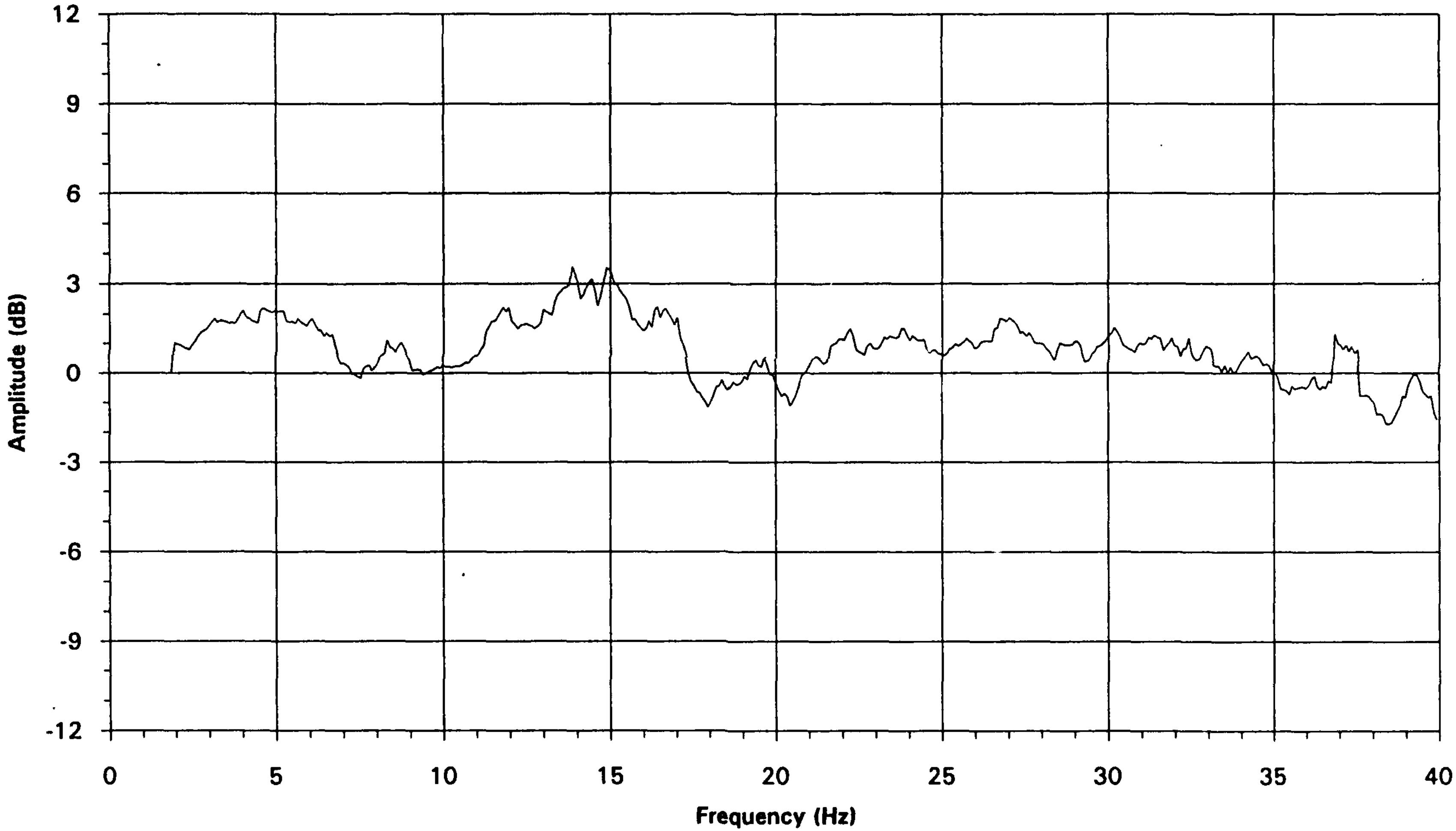


Figure 4-d. Transfer function for the standard set: back cushion, X-direction.

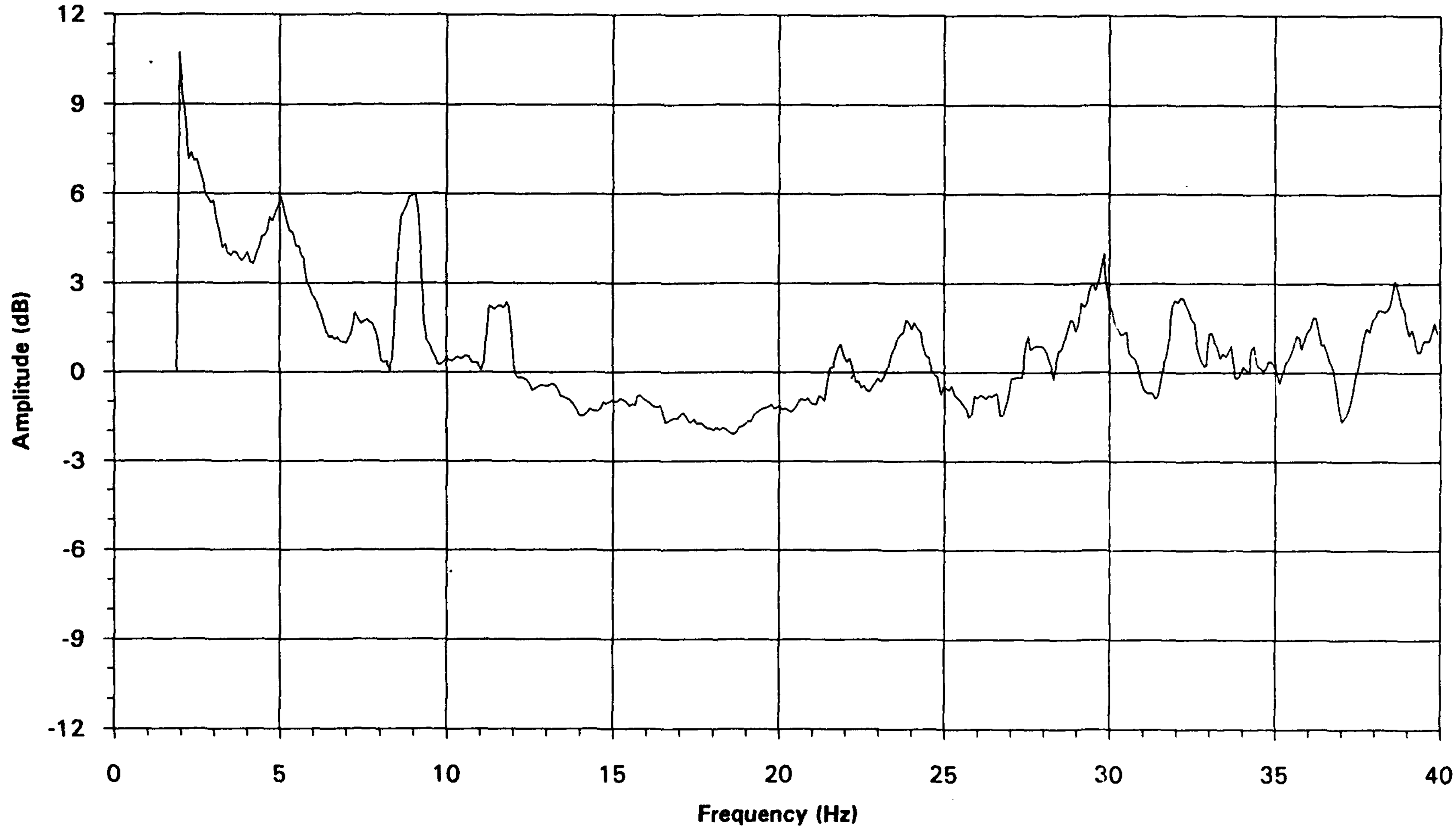


Figure 4-e. Transfer function for the standard set: back cushion, Y-direction.

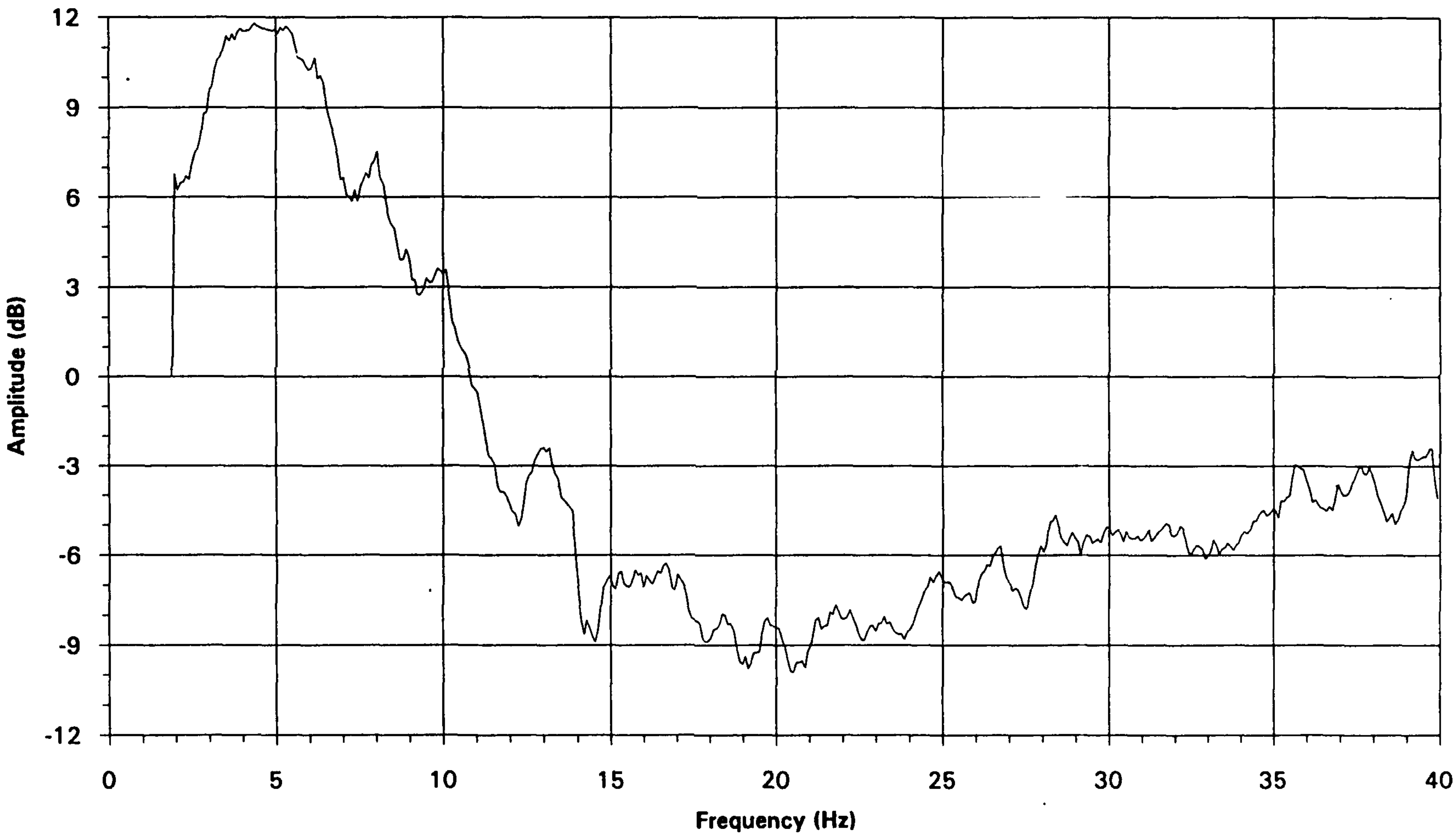


Figure 4-f. Transfer function for the standard set: back cushion, Z-direction.

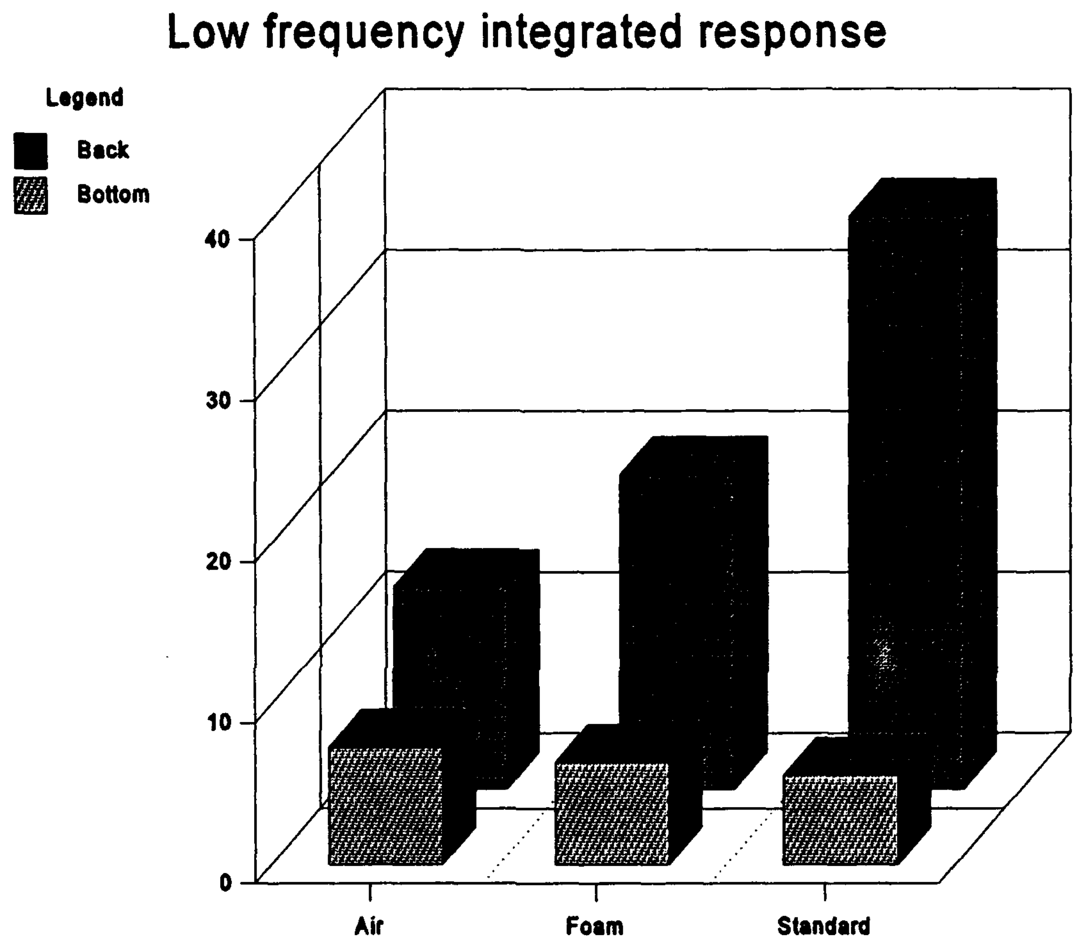


Figure 5. Low frequency integrated response for the seat back and seat bottom. Note that a positive response indicates an amplification.

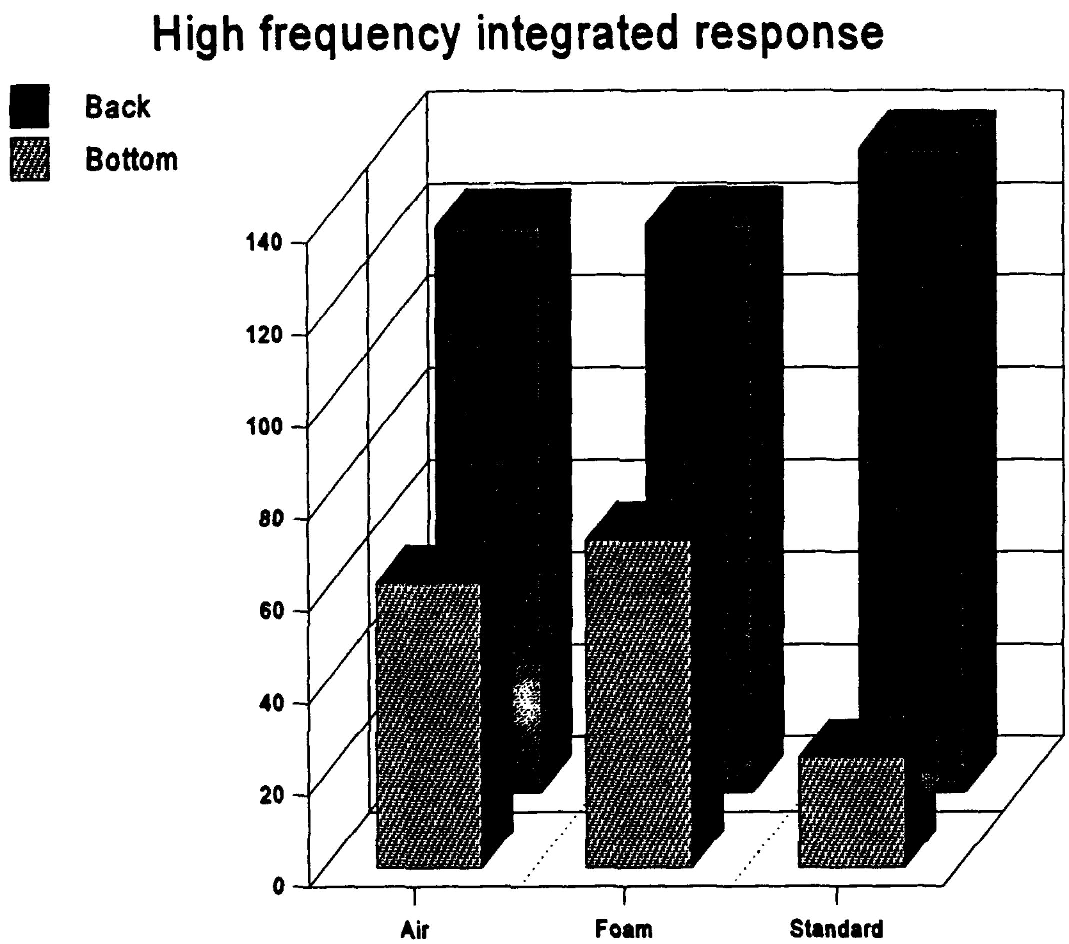


Figure 6. High frequency integrated response for the seat back and seat bottom. Note that a positive response indicates an attenuation.

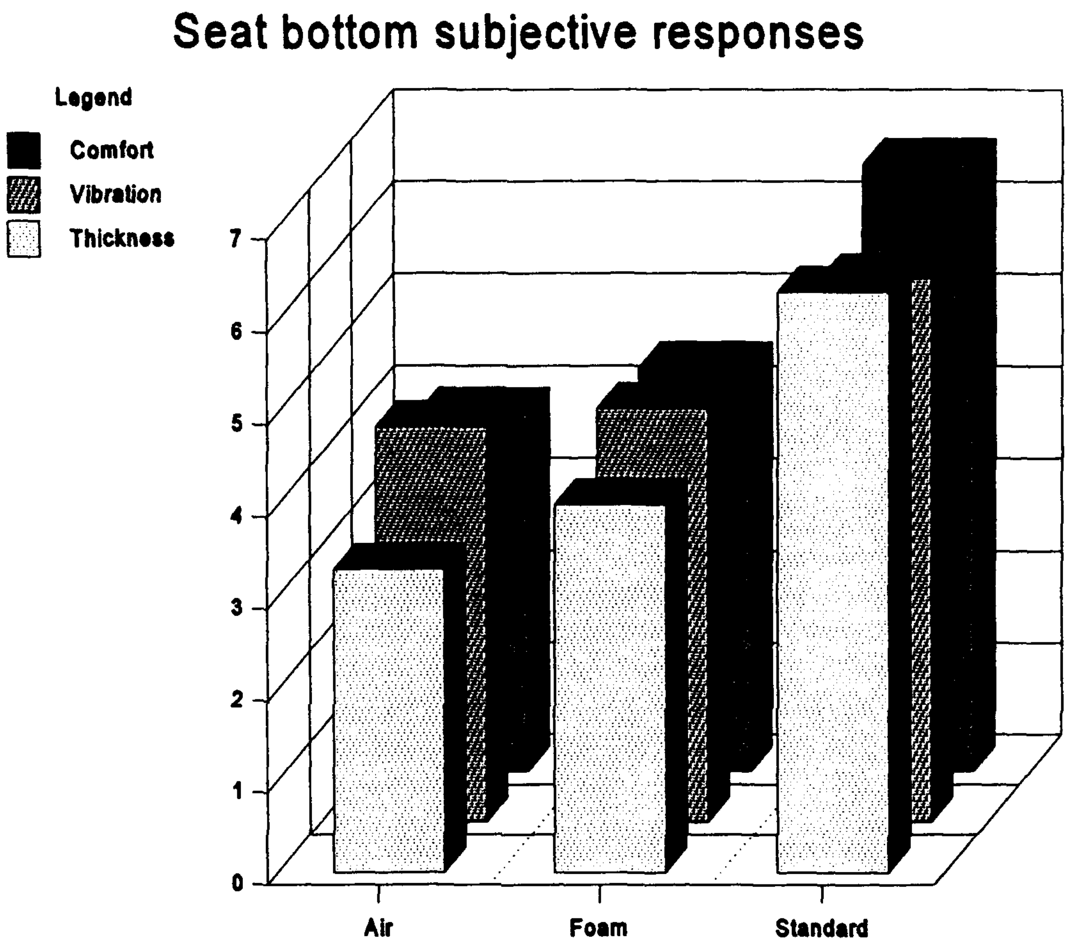


Figure 7. Subjective responses for the seat bottom. A lower score indicates a preference for the specified characteristic.

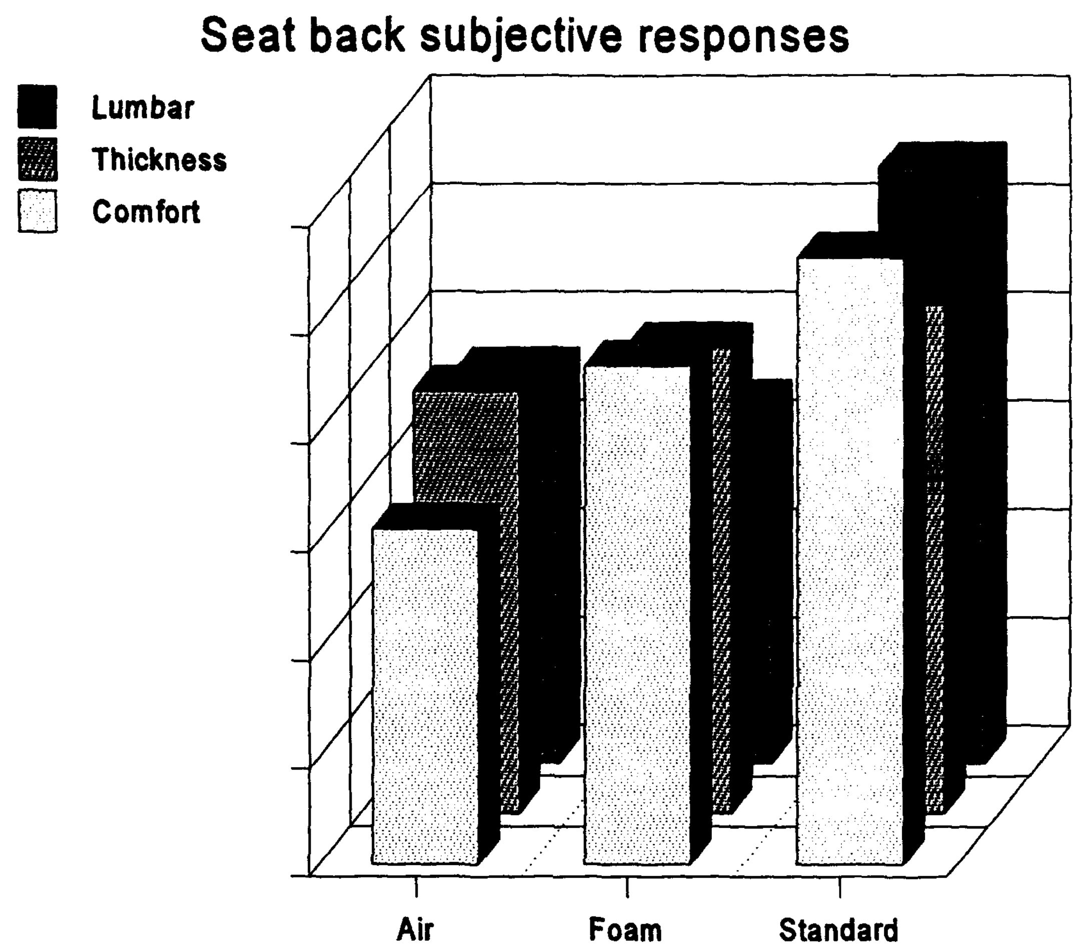


Figure 8. Subjective responses for the seat back. A lower scores indicates a preference for the specified characteristic.

Table 1.

Results of subjective evaluation of the armrests, lumbar supports, and thigh wedges.

Question	Response mean (SD)
Attachment method of the armrest to the seat bottom	4.8 (6.6)
Attachment method of the armrest to the thigh	5.0 (2.8)
Rate the interference of the inflatable arm support with the control stability of the cyclic	3.6 (2.1)
Rate the interference of the bean bag with the control stability of the cyclic	2.6 (2.3)
Rate the interference caused by the thigh support wedges with the operation of the cyclic	1.1 (0.4)
If you do not use the thigh support wedges, rate their interference (when stowed) with the operation of the cyclic	-- (--)
If you do not use the thigh support wedges, rate their interference (when stowed) with the seat height adjustment	-- (--)
Lumbar support: inflatable fixed	3.3 (2.1)
Lumbar support: inflatable adjustable	2.9 (3.5)
Lumbar support: adjustable foam	5.7 (1.4)
Armrest: bean bag	3.0 (2.4)
Armrest: foam	4.0 (1.9)

Appendix A.

List of manufacturers.

Accelerometers:
Bruel & Kjaer Instruments
185 Forest Street
Marlborough, MA 01752

Charge amplifiers:
Kistler Instrument Corporation
75 John Glenn Drive
Amherst, NY 14120

Windows & DOS:
MicroSoft Corporation
16011 NE 36th Way
P.O. Box 97107
Redmond, WA 98073-9717

Signal Processing Software:
HEM Data Corporation
17336 West 12 Mile Road
Southfield, MI 48076-2123

Tape recorder/playback:
TEAC Corporation of America
7733 Telegraph Road
Montebello, CA 90640

A/D Conversion PC card:
Keithly-Metrabyte Data Acquisition
440 Myles Standish Blvd
Tanton, MA 02780

Analog filters PC card:
Onsite Instruments, Inc.
855 Maude Avenue, #2
Mountain View, CA 94043

Statistical software:
Stystat, Inc.
1800 Sherman Avenue
Evanston, IL 60210

Appendix B.

List of contact addresses.

Commander
Aviation Applied Technology Directorate
ATTN: AMSAT-R-TV (Kevin Nolan)
Fort Eustis, VA, 23604

LME, Inc.
ATTN: Mr. Barry Shope
P. O. Box 6637
201 Defense Highway
Annapolis, MD 21401

Appendix C.

Medical screening questionnaire.

1. Name ____
   Last First MI
2. SSN: ____
3. Date of Birth: ________________
4. What was the date of your last medical (physical) examination?

____

5. What was the type of physical examination given?
   Class __I __IA __II __III __Army Entrance Physical __Other __Don't Know
6. Do you have, or have you ever had, any of the following medical problems?

	Yes	No
a. High blood pressure	__	__
b. Other heart problems	__	__
c. Recent broken bone (within last 6 months)	__	__
d. Muscle spasm	__	__
e. Back pain	__	__
f. Sprained or strained neck	__	__
g. Arthritis	__	__
h. Episodes of dizziness	__	__
i. Episodes of muscle weakness or paralysis	__	__
j. Headaches	__	__
k. Hormonal or glandular	__	__
l. Whip lash	__	__

7. Physical activities:

a. Are you actively engaged in any physical training program?
   __Yes __No

If so, how many hours per week do you spend in the following activities?

Run or jog	___	hours
Swim	___	hours
Tennis	___	hours
Softball	___	hours
Work with weights	___	hours
Football	___	hours
Basketball	___	hours
Others	___	hours

Describe: ______________________________________

b. How many hours have you flown in a helicopter in the last month?

Type of aircraft? __UH-1 __UH-60 __OH-58 __AH-64
__CH-47 __Other

8. Do you wear glasses or contact lenses to correct your vision?
___Yes ___No

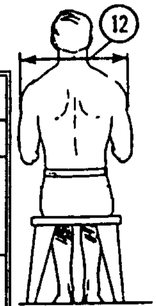
If so, please remember to wear them during this testing.

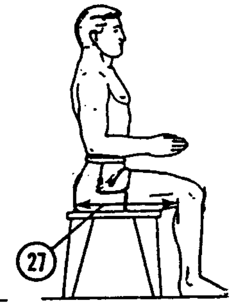
The above subject exhibits no evidence of medical conditions that could be adversely affected by participating this research protocol.

Medical Monitor Date

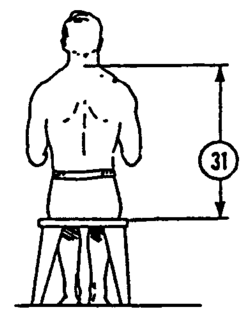
Appendix D.

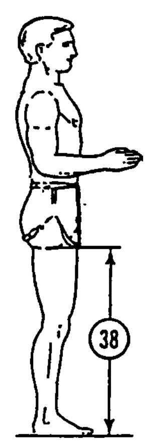
Anthropometric measurements.

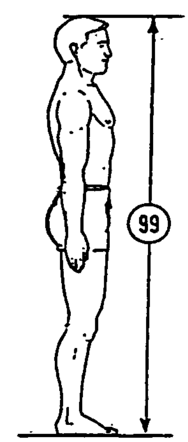


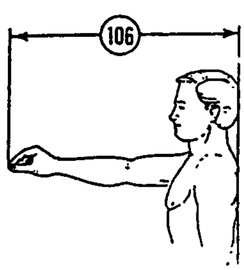


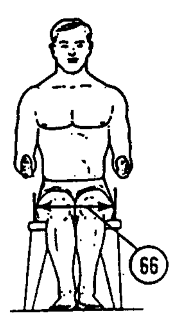
Dimension Descriptions		Design Values		
		Minimum	Mean	Maximum
12	**BIDELTOID BREADTH:** The maximum horizontal distance between the lateral margins of the upper arms and the deltoid muscles.	42.80 cm	49.57 cm	57.30 cm
27	**BUTTOCK-POPLITEAL LENGTH:** The horizontal distance between a buttock plate placed at the most posterior point on either buttock and the back of the knee.	44.40 cm	50.26 cm	57.70 cm
31	**CERVICALE HEIGHT,SITTING:** The vertical distance between and a sitting surface and the cervicale landmark on the spine at the base of the neck.	59.00 cm	68.89 cm	76.50 cm
38	**CROTCH HEIGHT:** The vertical distance between the standing surface and the crotch.	73.00 cm	84.18 cm	95.50 cm
49	**EYE HEIGHT,SITTING:** The vertical distance between a sitting surface and the ectocanthus landmark on the outer corner of the right eye.	70.70 cm	80.99 cm	90.30 cm
55	**FUNCTIONAL LEG LENGTH:** The straight-line distance between the plane of the bottom of the right foot with the leg extended and the back of the body of a seated subject.	98.10 cm	108.73 cm	122.50 cm
66	**HIP BREADTH, SITTING:** The distance between the lateral points of the hips of thighs.	31.90 cm	37.18 cm	45.30 cm
93	**SITTING HEIGHT:** The vertical distance between a sitting surface and the tip of the head.	81.90 cm	92.95 cm	102.10 cm
99	**STATURE:** The vertical distance from a standing surface to the top of the head.	157.90 cm	177.10 cm	194.10 cm
106	**THUMBTIP REACH:** The horizontal distance from a back wall to the tip of the right thumb.	70.50 cm	80.48 cm	92.60 cm
124	**WEIGHT:** Measure of heaviness or mass of subject.	56.90 kg	79.97 kg	113.60 kg

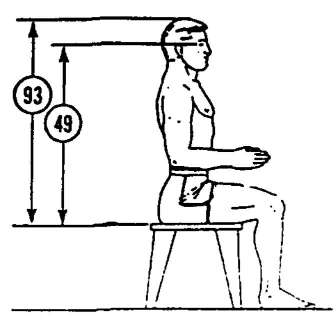


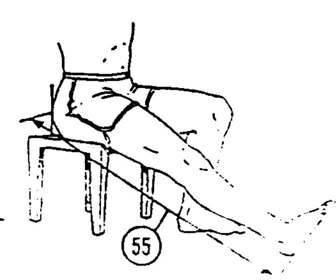












Subject number: ________________ Date: ____________

Subject's measurements.		Mean
Bideltoid breadth: ________	cm	49.57 cm
Buttock-popliteal length: ________	cm	50.26 cm
Cervicale height, sitting: ________	cm	68.89 cm
Crotch height: ________	cm	84.14 cm
Eye height, sitting: ________	cm	80.99 cm
Functional leg length: ________	cm	108.73 cm
Hip breadth, sitting: ________	cm	37.18 cm
Sitting height: ________	cm	92.95 cm
Stature: ________	cm	177.10 cm
Thumbtip reach: ________	cm	80.48 cm
Weight: ________	kg	79.97 kg

Appendix E.

Preride questionnaire.

Apache seat cushion study - Experience survey.

1. Flight experience: How many hours do you have in the following categories?	Total rotary-wing ______ AH-64 ______ AH-64 past 90 days ______
2. Do you have any history of back pain injuries or back problems that are NOT related to flying?	No. Yes.

If yes, describe.

3. Do you have any back discomfort that IS related to flying?	No. Yes.

If yes describe:

Aircraft:
Frequency:
Location of discomfort:
Duration of discomfort:

4. What problems have you noticed in the AH-64 seat cushion that may be corrected with a new seat cushion?

Cushion characteristics	Rating for seat bottom:						
	Too much			About right			Too little
Contour at buttock							
Contour at inner knee							
Overall thickness							
Length							
Width							
Firmness							
Covering material coarseness							
Covering material thickness							
Air circulation							
Hotness							
Seat pan angle (too much = slide out)							
Vibration absorption							
Add your own criteria for the seat bottom cushion:							

Question 4 (Continued).

Cushion characteristics	Rating for seat back.						
	Too much			About right			Too little
Contour at lower back							
Contour at upper back							
Location of lumbar support (too much = too high)							
Thickness of lumbar support							
Location of headrest (too much = too high)							
Thickness of headrest							
Overall thickness							
Length							
Width							
Firmness							
Covering material coarseness							
Covering material thickness							
Air circulation							
Hotness							
Seat back angle (too much = leaning back)							
Vibration absorption							
Add your own criteria for the seat bottom cushion:							

5. If you designed a new seat cushion for the AH-64, what features would you change or include?

Cushion characteristics	Rating for seat bottom:						
	Add a lot more			About right			Take a lot out
Contour at buttocks							
Contour at inner knee							
Overall thickness							
Length							
Width							
Firmness							
Covering material coarseness							
Covering material thickness							
Air circulation							
Hotness							
Seat pan angle (add more = knees lower)							
Vibration absorption							
Add your own criteria for the seat bottom cushion:							

Question 5 (Continued).

Cushion characteristics	Rating for seat back.						
	Add a lot more			About right			Take a lot out
Contour at lower back							
Contour at upper back							
Location of lumbar support (add more = make higher)							
Thickness of lumbar support							
Location of headrest (add more = make higher)							
Thickness of headrest							
Overall thickness							
Length							
Width							
Firmness							
Covering material coarseness							
Covering material thickness							
Air circulation							
Hotness							
Seat back angle (add more = lean back)							
Vibration absorption							
Add your own criteria for the seat back cushion:							

Appendix F.

Apache seat cushion study - postride survey.

Subject number _____

You were just exposed to a candidate seat cushion. Please rate the overall performance of that seat cushion.

Cushion characteristics	Rating for seat bottom:						
	Too much			About right			Too little
Contour at buttocks							
Contour at inner knee							
Overall thickness							
Length							
Width							
Firmness							
Covering material coarseness							
Covering material thickness							
Air circulation							
Hotness							
Seat pan angle (too much = slide out)							
Vibration absorption							
Overall comfort (change your rating here): Too much = very good Too little = very poor							
Add your own criteria for the seat bottom cushion:							

Postride survey (Continued).

Cushion characteristics	Rating for seat back.						
	Too much			About right			Too little
Contour at lower back							
Contour at upper back							
Location of lumbar support (add more = make higher)							
Thickness of lumbar support							
Location of headrest (add more = make higher)							
Thickness of headrest							
Overall thickness							
Length							
Width							
Firmness							
Covering material coarseness							
Covering material thickness							
Air circulation							
Hotness							
Seat back angle (too much = lean back)							
Vibration absorption							
Overall comfort (change your rating here) Too much = very good Too little = Very poor							
Add your own criteria for the seat back cushion:							

Appendix G.

Interference questionnaire.

Cushion characteristic	Rating						
	Like very much			Indif-fer-ent			Dis-like
Attachment method of the armrest to the seat bottom cushion							
Attachment method of the armrest to the thigh							

What is your preferred location for the thigh support inflator bulb? ____ Right side of seat bucket ____ Left side of seat bucket ____ Other: ______________________________

What is your preferred location for the lumbar support inflator bulb? ____ Right side of seat bucket ____ Left side of seat bucket ____ Other: ______________________________

Cushion characteristic	Rating						
	No inter-fer-ence			Minor but toler-able			Un-accept-able
Rate the interference of the inflatable arm support with the control stability of the cyclic							
Rate the interference of the "bean bag" arm support with the control stability of the cyclic							
Rate the interference caused by the thigh support wedges with the operation of the cyclic							
If you do not use the thigh support wedges, rate their interference (when stowed) with the operation of the cyclic							
If you do not use the thigh support wedges, rate their interference (when stowed) with the seat height adjustment							

You have completed an independent evaluation of two candidate seat cushion sets along with the standard Apache seat cushion set. We would now like to know how you would compare the lumbar supports and the arm rests against each other. We will introduce a third candidate seat cushion at this time with an integral inflatable lumbar support. The lumbar supports you will compare are:

- inflatable fixed
- inflatable adjustable
- foam adjustable

Similarily, we have three arm rests that we would like you to compare to each other. The three arm rests are:

- bean bag
- inflatable
- foam

Please let us know if you would like to see the equipment, or try them out on the seat, without ride motion, to help you make your evaluation.

Cushion accessories	Rating						
	Like very much			Indif- fer- ent			Dis- like
Lumbar supports:							
Inflatable fixed							
Inflatable adjustable							
Adjustable foam							
Armrests:							
Bean bag							
Inflatable							
Foam							

Appendix H.

Data tables.

Table 1.

Low frequency integrated response for the seat back and seat bottom. Note that a positive response indicates an amplification. Standard deviations given in parenthesis.

	Cushion type		
Cushion location	**Air**	**Foam**	**Standard**
Back	12.3(6.9)	19.6(7.5)	35.6(8.1)
Bottom	7.3(3.1)	6.3(5.0)	5.6(2.8)

Table 2.

High frequency inetgrated response for the seat back and seat bottom. Note that a positive response indicates an attenuation. Standard deviations given in parenthesis.

	Cushion type		
Cushion location	**Air**	**Foam**	**Standard**
Back	122.9(70.8)	123.3(111.6)	139.7(56.4)
Bottom	61.9(39.9)	71.3(33.5)	24.1(18.5)

Table 3.

Subjective responses for the seat bottom. A lower score indicates a preference for the specifed characteristic. Standard deviations given in parenthesis.

	Cushion type		
Cushion characteristic	Air	Foam	Standard
Comfort	3.9(0.4)	4.4(1.3)	6.6(0.7)
Vibration	4.3(1.3)	4.5(1.1)	5.9(1.1)
Thickness	3.3(2.0)	4.0(2.2)	6.3(1.5)

Table 4.

Subjective responses for the seat bottom. A lower score indicates a preference for the specifed characteristic. Standard deviations given in parenthesis.

	Cushion type		
Cushion characteristic	Air	Foam	Standard
Comfort	3.6(1.1)	3.3(1.7)	5.5(1.1)
Vibration	3.9(0.4)	4.3(0.8)	4.7(0.9)
Thickness	3.1(1.4)	4.6(1.5)	5.6(1.4)

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